Part II

Inventions That Changed The World

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Nehru Bal Pustakalaya

INVENTIONS THAT CHANGED THE WORLD

(PART 2)

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Illustrations

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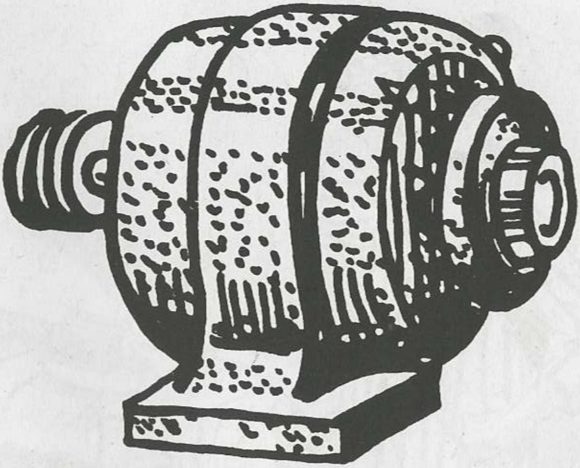


THE DYNAMO

Cheap and plenty of electric power is a great blessing to a country. In the home it not only gives heat and light but also works a number of gadgets of everyday use. We use electric irons, electric toasters, electric ovens, electric bells, electric coolers, vacuum cleaners, washing machines, electric razors, etc. to make life easy and comfortable.

Electricity is used to run trains and trams, and machines in workshops and factories. It is required to operate telegraphs, telephones, radio and television. The uses of electricity are so many that we wonder how we did without it.

Yet 150 years ago people had to do without it; not because electricity was not known, but because it was difficult and expensive to produce. It was only produced in small quantities by scientists for experiments. The in-

vention of the dynamo or electric generator brought electric power within the reach of everyone.

Electricity was known long, long ago. Six hundred years before Christ, a Greek philosopher discovered that if a piece of amber was rubbed with silk cloth, it behaved in a strange way. It picked up any light object that was brought near it. Little bits of fluff, paper, tiny shreds of cloth and feathers seemed to jump onto the piece of amber and stick to it. This might have caused some entertainment but nothing concrete followed till about 1600 when William Gilbert who was studying electricity as a hobby made careful experiments with various materials. He found that besides amber, substances like sulphur, glass and sealing-wax also attracted bits of paper when rubbed with suitable substances such as silk, flannel or fur. He was the first to use the word 'electricity' which is derived from 'electron', the Greek word for amber. This was the starting-point of the modern science of electricity which was to transform the world.

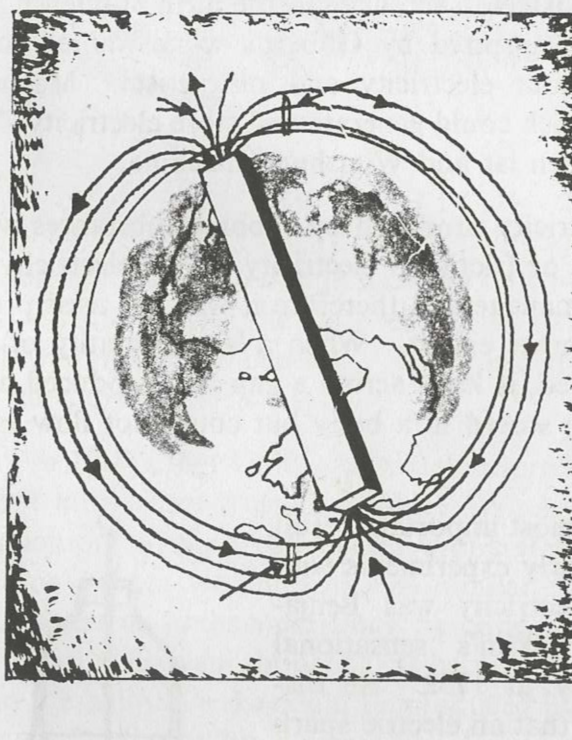
Even before the Greeks learned about electricity they discovered a kind of stone that attracted bits of iron to itself. This stone is an oxide of iron found in the natural state in Greece, North America and Sweden. The mineral was at first found in large quantities in Magnesia, a district in ancient Greece, and was called 'magnesia stone'. From this the word magnet was derived.

Today artificial magnets are made with the help of

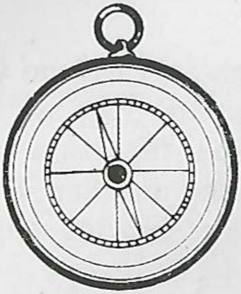
electric current. Artificial magnets are generally made in two forms. The most common are straight bars known as bar magnets. Those which are curved like the letter U are called horse-shoe magnets. These two types of magnet have many uses. The bar magnet proved especially useful to sailors.

It was found that if a bar magnet was freely suspended by a string tied to its centre it always sets in a definite direction. This is the North-South direction. Before this

discovery sailors who sailed the high seas had no way of guiding their ships in the right direction. The sea looked the same on all sides. Only the sun, the moon and the stars could give them any idea of the direction in which they were sailing. But cloudy skies hid the stars, the



Magnet, when freely suspended, sets in a North-South direction



Compass

moon and even the sun for days on end. Now since a bar magnet always pointed to the North, sailors were able to use it as a compass to show them the direction in which the ship was moving at any time.

The sixteenth century saw the birth of science in Europe. Scientists inspired by Gilbert's work wanted to find out more about electricity and magnetism. Machines were made which could generate and store electricity. They were the Leyden jar and Wimshurst machine.

Electricity produced by rubbing substances was known as static or frictional electricity. This electricity was difficult to manage and therefore it was not used productively to any great extent. When a large quantity of electricity was stored, it leapt across a gap and produced a spark. It could be stored in a body but could not flow in a steady current.

The most important result of the early experiments with static electricity was Benjamin Franklin's sensational discovery in 1752. He discovered that an electric spark was similar to a flash of lightning.

Lyden Jar

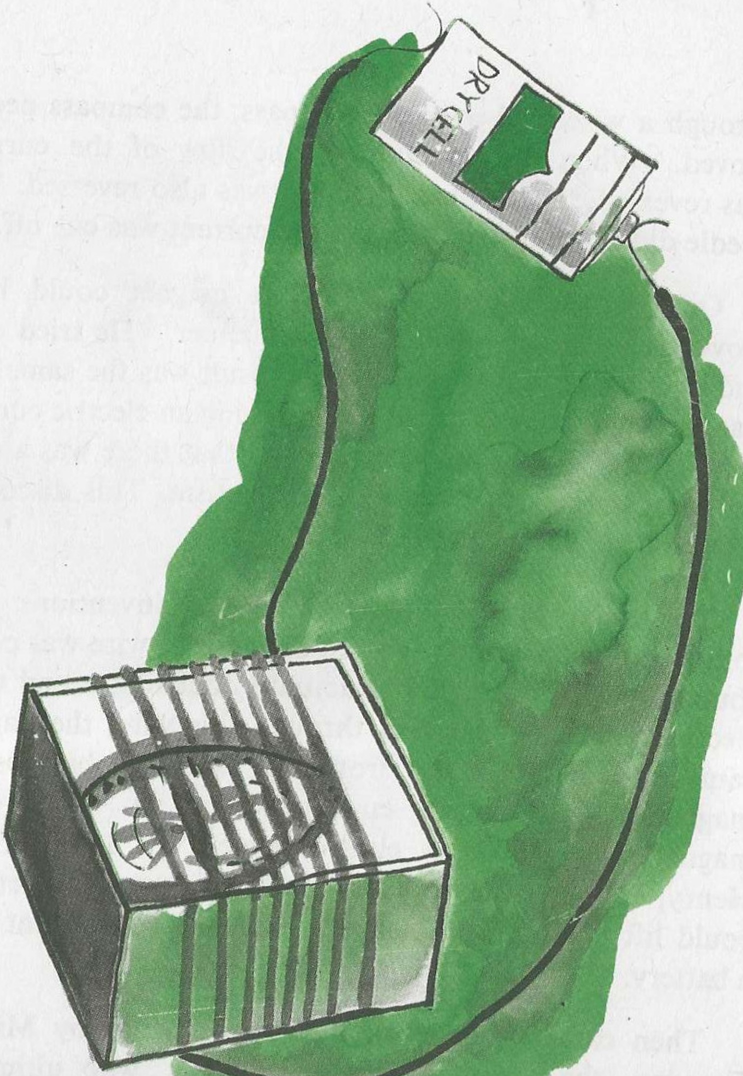
The problem now was to obtain a steady flow of electricity. This was solved with the discovery of the dynamo at the end of the eighteenth century. This opened a new chapter in the story of electricity.

One day in 1789 Luigi Galvani, an Italian professor of anatomy, left a dissected frog on a table. When he happened to touch one of the frog's nerves with a steel instrument, the frog gave a violent kick. A similar twitching was noticed when its limbs were hung by copper skewers from an iron rail. Galvani thought that because there was electricity in the animal, jerks could be produced by touching the nerve of a limb with a zinc rod. Jerks were also produced if a muscle was touched with a copper rod in

contact with zinc. This came to be known as animal electricity or galvanism. But another Italian professor, Alessandro Volta, disagreed with this theory. He believed that there was no electricity in the animal but that electricity was generated by the contact of two dissimilar metals and the moisture of the flesh. He took several discs of zinc and copper and placed a cardboard moistened with salt solution between each pair. Thus a pile was made, arranging the metals alternately with zinc at one end and copper at the other. Electricity was produced when the ends were connected. This arrangement was called a voltaic pile or a voltaic cell. Thus the first electric battery was produced. Various types of cells were made one after another, each an improvement on the other. Even today we use these cells where small steady currents are required, as in telephone operations. These types of cells are known as primary cells. Then there are secondary cells or accumulators which store electricity and discharge a steady current. These are commonly used in motor-cars and buses.

The current obtained from batteries was too weak and costly to produce. It, therefore, became necessary to find some way of producing electricity cheaply and in plenty. The search continued.

The next important discovery was made in 1820 by Hans Oersted, a Danish physicist. One day he was showing his students some experiments with an electric current. Quite by chance there was a compass lying on the table where he was working. Oersted noticed that when the current flowed



Oersted discovered that electricity and magnetism were related

through a wire held over the compass, the compass needle moved. When the direction of the flow of the current was reversed, the needle's direction was also reversed. The needle did not move at all when the current was cut off.

Oersted was surprised. Only a magnet could have moved the compass needle in this manner. He tried over and over again, but every time the result was the same. He was forced to believe that a wire carrying an electric current behaved like a magnet. This proved that there was a connection between electricity and magnetism. This discovery created a stir in the world of science.

The electromagnet was one of the inventions that followed this discovery. When a length of wire was coiled round a bar of iron without actually touching it and when electric current was passed through this wire, the bar became a magnet. If soft iron was used, the bar lost its magnetism as soon as the current was cut off. This type of magnet was called an electromagnet. In 1821, Joseph Henry, an American scientist, made an electromagnet that could lift a ton of iron, using only the electric current from a battery.

Then came the invention of the dynamo by Michael Faraday, the son of a poor blacksmith, who ultimately became a great scientist and the President of the Royal Society. Faraday entered the service of a book-binder at the age of 13. But he was more interested in what was inside the books than in the covers he put on their outsides. He

read all the books that came to him, but his real passion was for science books.

Faraday's master was a kind man and allowed him to read as much as he liked. One day a customer gave Fara-

day tickets for some science lectures that were being given by a famous scientist Humphry Davy of the Royal Society of London. Faraday heard these lectures with great interest and made careful notes of what he had heard. Sometime later he bound these notes and sent them to Davy requesting a job in his laboratory. He made it clear that he did not mind what kind of job it was as long as it gave him a chance to work there.

Davy called Faraday and, finding him very eager, gave him the job of washing bottles and cleaning the laboratory.

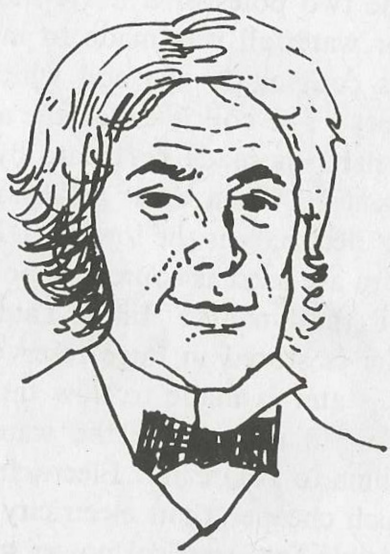
Faraday took great interest in the experiments that were being conducted. As he picked up knowledge he began some experiments of his own. He soon made remarkable progress. Scientists began to take notice of his work. In time he became an eminent scientist and was made a member of the Royal Society.

It is said that Sir Humphry Davy was once asked what was the greatest discovery he had made in his life. He replied that his greatest discovery was Faraday.

Faraday heard of Oersted's discovery that an electric current produces a magnetic effect around the wire through which it passes. He asked himself, If an electric current could create a magnet where there was none before, why can't a magnet produce an electric current?

He started working on this idea. The principle on which he worked is easy to understand. Consider a length

of wire coiled round a piece of cardboard rolled in the form of a cylinder. The two ends of this wire were connected to an instrument called the galvanometer which measures electric current. A bar magnet was placed in the cylinder.



Michael Faraday

Faraday was disappointed when the needle of the galvanometer did not move. One day he pulled the magnet out in disgust to throw it away. Suddenly the needle moved. Thus Faraday found that current was generated

only when the magnet moved in or out, not when it was motionless. The more rapidly the magnet moved, the more powerful was the current. The strength of the current also increased with the number of turns of the coil. Based on these observations Faraday made the first dynamo. Instead of moving a bar magnet to and fro he made a coil of wire rotate between the two poles of a horse-shoe magnet. A rushing stream or waterfall was made to move a Persian wheel which was coupled to the coil which moved and generated electricity. The coil is called the armature. The armature of a dynamo is made to rotate by steam, water power or gas engines. When water power is available, the cost of producing electricity is the lowest. The huge water-falls of the Niagara are used as sources of power to turn the turbines coupled to the dynamo. In the Tata hydro-electric scheme rain water is stored in huge reservoirs on a high level from where water is made to flow through pipes to turn the turbines. In either case the water falls on the vanes of the turbine to rotate it. Electricity produced in this way was much cheaper than electricity from batteries and made it possible for electrical power to be used on a large scale.

Electricity has many advantages over steam as a source of power. One can just turn on a switch when power is needed and switch it off when it is not required. Its production is quicker and cleaner than the power obtained from burning coal or oil which gives off smoke and poisonous gases. Moreover, ashes or burnt cinders are not left behind if electricity is used.

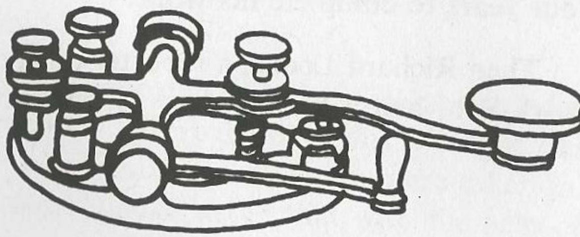
It is also easier to transmit electrical energy over long distances through wires. Though the initial cost is heavy, the running cost is low and electric current flows along

these wires without any trouble.

The reverse of the dynamo is the electric motor. In a dynamo the coil is rotated to generate electricity, whereas

in an electric motor, electricity is made to rotate the coil. An electric motor is required for fans, pumps, trams, electric trains and all kinds of machinery. An electric motor is constructed the same way as a dynamo, with the same essential parts.

The use of electricity has started a new branch of science known as electronics. In a later chapter we shall see what far-reaching changes this new science is bringing about.



THE TELEGRAPH

In 1833 John Herschel, a British astronomer, went to South Africa to study the southern skies. He took with him a powerful telescope and many other instruments. He wanted to make charts and maps of the sky which people in the northern half of the world never saw. John Herschel planned to stay at the Cape of Good Hope for three or

four years to complete his work.

Then Richard Locke, a reporter on the staff of the New York Sun, had a bright idea. Whatever he wrote about

John Herschel's discoveries would be believed as there was no means of verifying it. No one would find out the truth unless he sent a man or message by ship to South Africa, and even then it would take months to receive a reply from

the astronomer. In the meanwhile, Locke decided to have all the fun he could.

In his first article he reported that Herschel had invented a new kind of telescope. Every detail of this telescope was so cleverly thought out that even scientists were taken in. Then the fun started. Locke wrote that with the help of this wonderful telescope, Herschel had seen that the hills and mountains on the moon were made of precious stone. Several forms of life were also reported to have been discovered. Monsters, shaped like huge round balls, rolled about at dizzy speeds over the sands of the lunar sea-shore.

Readers were thrilled and believed the tall tales told by Locke. Locke did the job so well that even scientists were deceived.

Months later, the news came that the whole story was a big hoax, the greatest in the history of science!

No one would dream of playing such a trick nowadays. Thanks to the discovery of the telegraph, we can get news across continents and oceans within minutes.

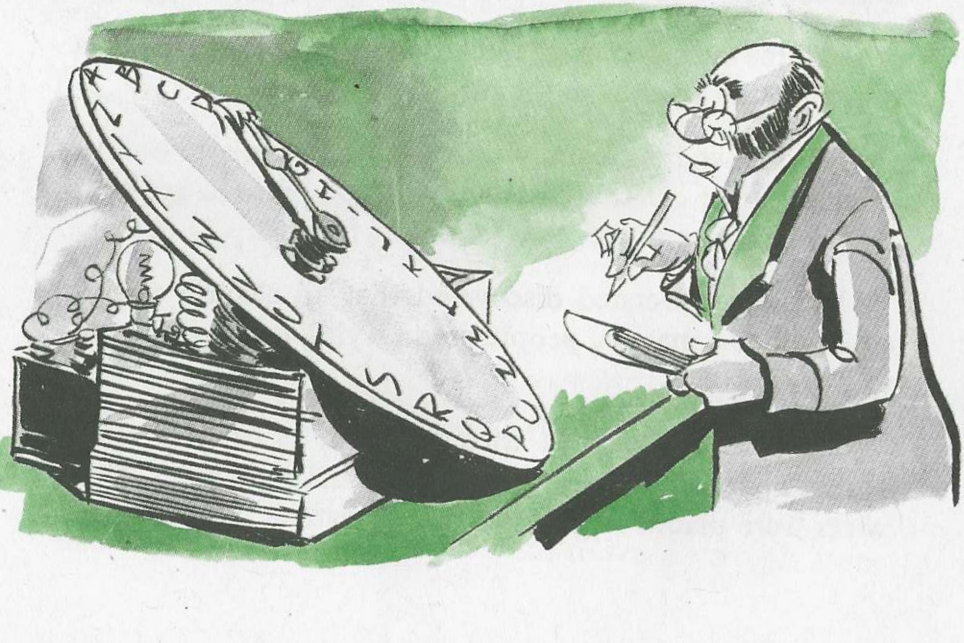
Ever since Oersted discovered that an electric current could move a magnet, people began trying to put electricity to work.

An Austrian scientist tried a system as early as 1809. He set apart one wire for each letter of the alphabet. These wires were placed in a vessel full of water. When electri-

city passed through any of the wires, a tiny bubble appeared at its base. Though this invention made quite a stir, it did not prove very useful.

Later, around 1825, another inventor, Baron Schilling, made a magnetic telegraph. The electric current passing through the wire turned a magnetic needle which moved over black and white spaces marked on a card. Schilling used a code in which 'black-white' meant one letter, 'black-black-white' meant another, and so on.

An English professor, Charles Wheatstone, made a small change in this instrument in 1837. He made the needle move over a dial the rim of which was marked with figures



and letters. Messages could be read by watching the needle move from letter to letter. It was slow work, but the Railways found it useful and the instrument was in use for years. Wheatstone made a fortune.

Then came Samuel F. B. Morse, the real inventor of the telegraph in its modern form.

One would hardly have expected Morse to make this invention. He was born in America, and although he studied science at school, he chose to be an artist and became quite famous as a portrait painter. Then he went on a tour of Europe to see famous works of art.

He heard about the telegraph when he was returning from Europe on board a ship. A fellow traveller, who was a scientist, spoke to him of the work being done on electricity in France. He also showed Morse a small electromagnet he was taking with him to America.

This set Morse thinking. If an electric current could flow any distance through a wire, why shouldn't it be made to carry messages?

It was an intriguing thought. He had to paint, however, and so he continued to paint, but the idea stuck in his head. His friend, Dr. Gale, at New York University, was pleased at his enthusiasm and encouraged him to work in the college laboratory.

Gale knew of Joseph Henry, a pure scientist, who had

done some work in this field. Joseph Henry always helped anyone who came to him with scientific problems. He helped Morse too and showed him a telegraph line about five kilometres long which he had laid in 1832. It created an electromagnet which swung and struck a gong. A code was used for sending and reading messages from the sound of the gong.

Morse decided to use this device, but he had still two problems to solve. The device had only been operated over a distance of five kilometres, and Morse wanted his telegraph to operate over hundreds of kilometres. Besides, Morse did not like the code Henry had used. He wanted to find a better code.

Joseph Henry helped to solve the first problem. A device known as a 'relay' was fitted at various points along a line. It was just a coil of wire with a battery placed at the end of each section to boost up the fading signals.

To solve the next problem, Morse invented the famous 'Morse Code' which is used even nowadays for all types of signalling, especially in the army and the navy. It consists of dots and dashes and each group of these stands for a letter of the alphabet.

Morse took out a patent for his invention in 1837, and tried to persuade the Government to use it on a large scale. But there were delays and for five years Morse led a life of poverty and neglect. At last, the Government gave him

MORSE CODE

A · –		R · – ·
B – · · ·	J · – – –	S · · ·
C – · – ·	K – · –	T –
D – · ·	L · – · ·	U · · –
E ·	M – –	V · · · –
F · · – ·	N – ·	W · – –
G – – ·	O – – –	X – · · –
H · · · ·	P · – – ·	Y – · – –
I · ·	Q – – · –	Z – – · ·

$30,000 for a test to show the value of his invention. Morse laid a line of wire from Washington to Baltimore—a distance of about 65 kilometres. The wires were carried overhead, supported by poles, and a battery of 100 cells was used to supply the current. On May 24, 1844, the first message was sent and received. It read "What hath God wrought?" Indeed, God had wrought a miracle that was fated to change the world.

The test was a complete success. The American Government took a long time making up its mind about going in for the telegraph in a big way. But private businessmen came forward and soon telegraph wires began to hum over the whole country.

Scientists and inventors were quick to see that anyone who could find a way of sending more than one message over the same wire would make a fortune. A young man, Alexander Graham Bell, was one of those who became interested. He had, moreover, the good fortune to make an even greater invention—the telephone. Bell, who used to teach the deaf, had studied the construction of the human

ear to see how it responded to sound. He had the idea of making speech visible so that the deaf could see it by means of a vibrating needle.

Any sound sets up waves of pressure in the air which spread out all around, like ripples when a stone is thrown into a pond. A sound is heard when the pressure waves reach the ear and make the eardrum and the small bone behind it vibrate or start moving forward and back. Similarly when you speak into a telephone the pressure waves strike a flexible iron diaphragm (a thin disc) which moves forward and backward, with the sound waves produced by the voice. In other words, the diaphragm is made to vibrate.

One day, Bell was working with his partner, Watson, in a laboratory. They were carrying out an experiment with a strip of metal which was being made to vibrate. The strip got struck. Watson plucked it, and the sound it made travelled along the wire to Bell, who was working in the next room. He rushed out to see what the matter was. He was thrilled when he saw what had happened. God had wrought another miracle!

Alexander Graham Bell

Bell had to work for another year before he succeeded in perfecting his invention. His apparatus consisted of a horn-shaped speaking tube, at the narrow end of which was a flat disc. This vibrated to the sound waves made by

the voice speaking into the tube. The vibration set up variations of electric current in an electromagnetic coil.

And then these variations travelled along the connecting wire to a receiving apparatus where the vibrations of a second diaphragm made the same sound waves in the air as those originally made by the speaker at the other end.

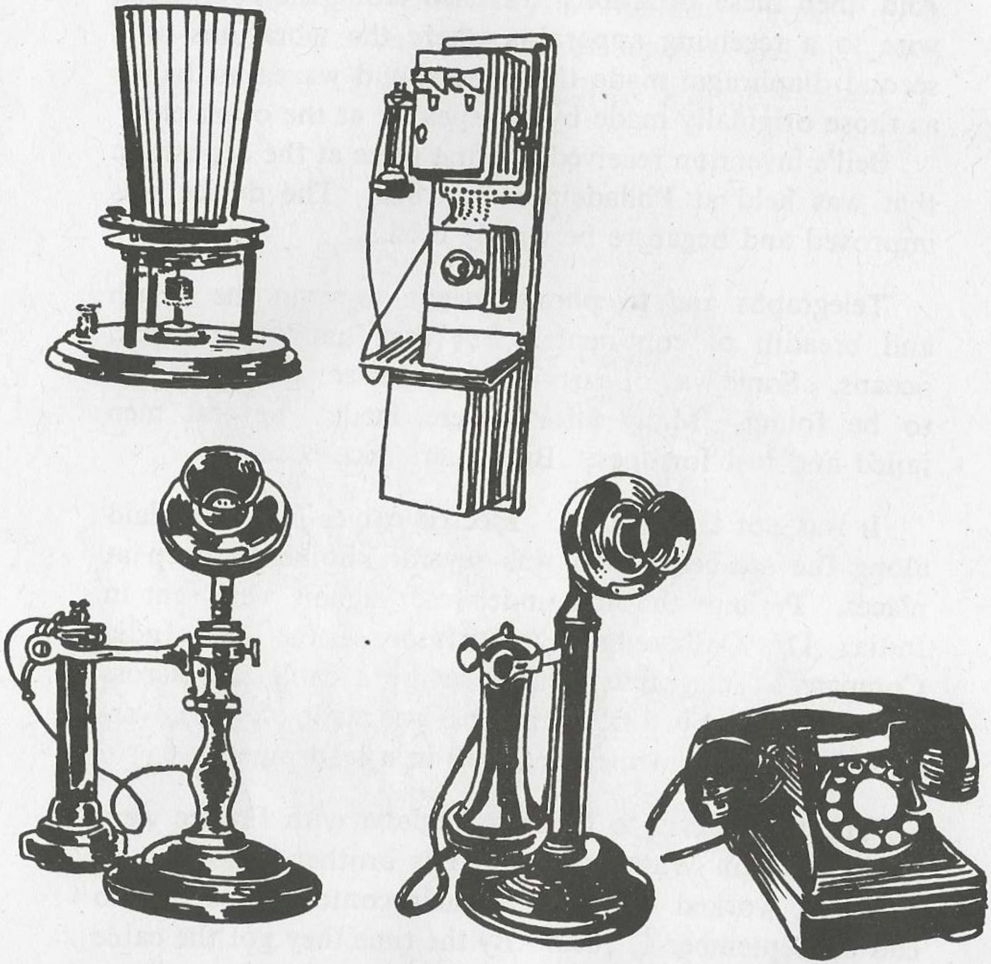
Bell's invention received the first prize at the exposition that was held at Philadelphia in 1876. The device was improved and began to be widely used.

Telegraphs and telephones began to span the length and breadth of continents. But they had yet to span oceans. Some way of carrying the wires across the sea had to be found. Many efforts were made. Several men failed and lost fortunes. But others succeeded.

It was not an easy job. Electric cables had to be laid along the sea-bed which was several kilometres deep at places. Perhaps the first underwater signals were sent in India. Dr. O'Shaughnessy, Director of the East India Company's Telegraphs, sent them by a cable laid across the Hoogly river in 1839. His cable was made of wire covered with rubber and then enclosed in a lead pipe.

The first efforts to link up England with France were made by John Watkins Brett. His brother, who was an engineer, worked with him. Their contract was due to end on September 1, 1850. By the time they got the cable ready, they had only three days left for laying it. They just got through a message and thus fulfilled their contract.

The next morning the line went completely dead. The cable had got caught in the anchor of a fishing boat and



The evolution of the telephone—from the earliest model to the latest

the fisherman had cut off a piece to show to his friends.

The task of laying a cable across the Atlantic was a gigantic one. Americans and Englishmen worked together and the navies of the two nations helped. After many setbacks and fa lures the work was completed in 1866. The cable ran from Valentia Bay near the south-west tip of Ireland to Newfoundland and then on to Canada. Europe thus joined hands with America across the Atlantic!

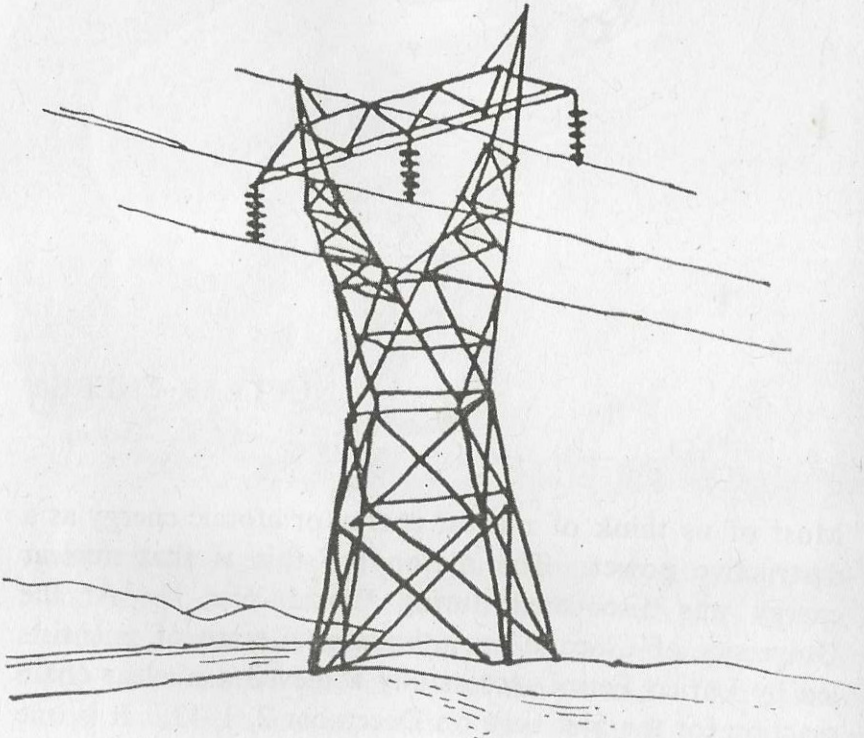
After 1866, many other undersea cables were laid. In 1870 Britain and India were linked. Formerly it took a telegram one week to reach Bombay from England. Usually messages were transmitted in relays by one station receiving and passing a message onto the next station. This resulted in many mistakes and it often became difficult to make out the original message. After undersea cables were laid, messages could be sent within minutes.

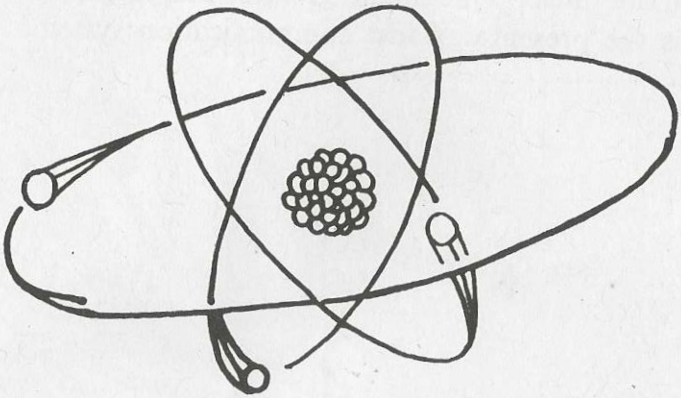
As time passed many new inventions were made. We have already seen how the telephone carried the human voice across thousands of kilometres. Then came the radio and the television.

Nowadays a man can read what is happening all over the world in his morning newspaper. News from the farthest corners of the earth is flashed, received and printed overnight.

Today we are on the threshold of a new era in telecommunications. Very soon we are going to have new

global telegraph, telephone and television services *via* communication satellites. One of the greatest achievements of mankind is the present-day fast communication system.





NUCLEAR ENERGY

Most of us think of nuclear energy or atomic energy as a destructive power. The reason for this is that nuclear energy was discovered during World War II. At the University of Chicago an international team of scientists led by Enrico Fermi successfully achieved a nuclear chain reaction for the first time on December 2, 1942. It is one

of the great tragedies of science that a source of power which could benefit mankind so greatly could also be the means of bringing untold misery and destruction.

The first atomic bomb to be used in warfare was drop-

ped on the Japanese city of Hiroshima on August 6, 1945 and three days later another atomic bomb was dropped over the industrial city of Nagasaki. Both were exploded 600 metres above the surface of the ground. The destruction was tremendous. Both the beautiful cities were

completely wrecked. Houses were reduced to ashes. Men, women and children were killed or maimed. It is estimated that over a lakh people died and about 75,000 were missing or injured as a result of the two explosions.

What is atomic energy? To understand this we must first know what is matter, an element, a molecule and an atom.

Matter is the name given to the materials of which the

earth, the sun, the planets and the stars are all made. All matter consists of a few pure substances which cannot be broken up into anything simpler. These pure substances are known as elements. The total number of elements found in nature is 92. Scientists have produced about a dozen more in their laboratories. The lightest of the former is hydrogen and the heaviest uranium. Most of these elements are ordinary solids, e.g. iron, silver, cop-

per and lead; others like bromine and mercury are liquids and some are gases like chlorine and oxygen. When elements combine to form an entirely new substance, it is called a compound. For instance, water which covers three-fourths of the globe is a compound composed of two elements—oxygen and hydrogen. In compounds the elements always combine in a definite proportion. The compound has its own properties. As we all know, water has many uses—one of them is to put out fire. But of the two elements that make up water, hydrogen is inflammable and oxygen actively supports combustion.

If we take a piece of any substance, say chalk, and break it into small bits, every bit of chalk will have the same properties as the original piece of chalk had. If we go on dividing the chalk till we reach a stage when further breaking of the bits would not be possible, the smallest possible particle which has the properties of the original chalk is known as a molecule (meaning little mass) of chalk.

This molecule of chalk is a compound of three elements—calcium, carbon and oxygen. If it is broken up into these elements, it will cease to be chalk.

A molecule of water is made up of two atoms of hydrogen and one atom of oxygen. You can get a rough idea of the minuteness of a molecule of water by picturing that there are about as many molecules in a raindrop as there are drops of water in the Mediterranean.

Now let us take an element such as iron and keep split-

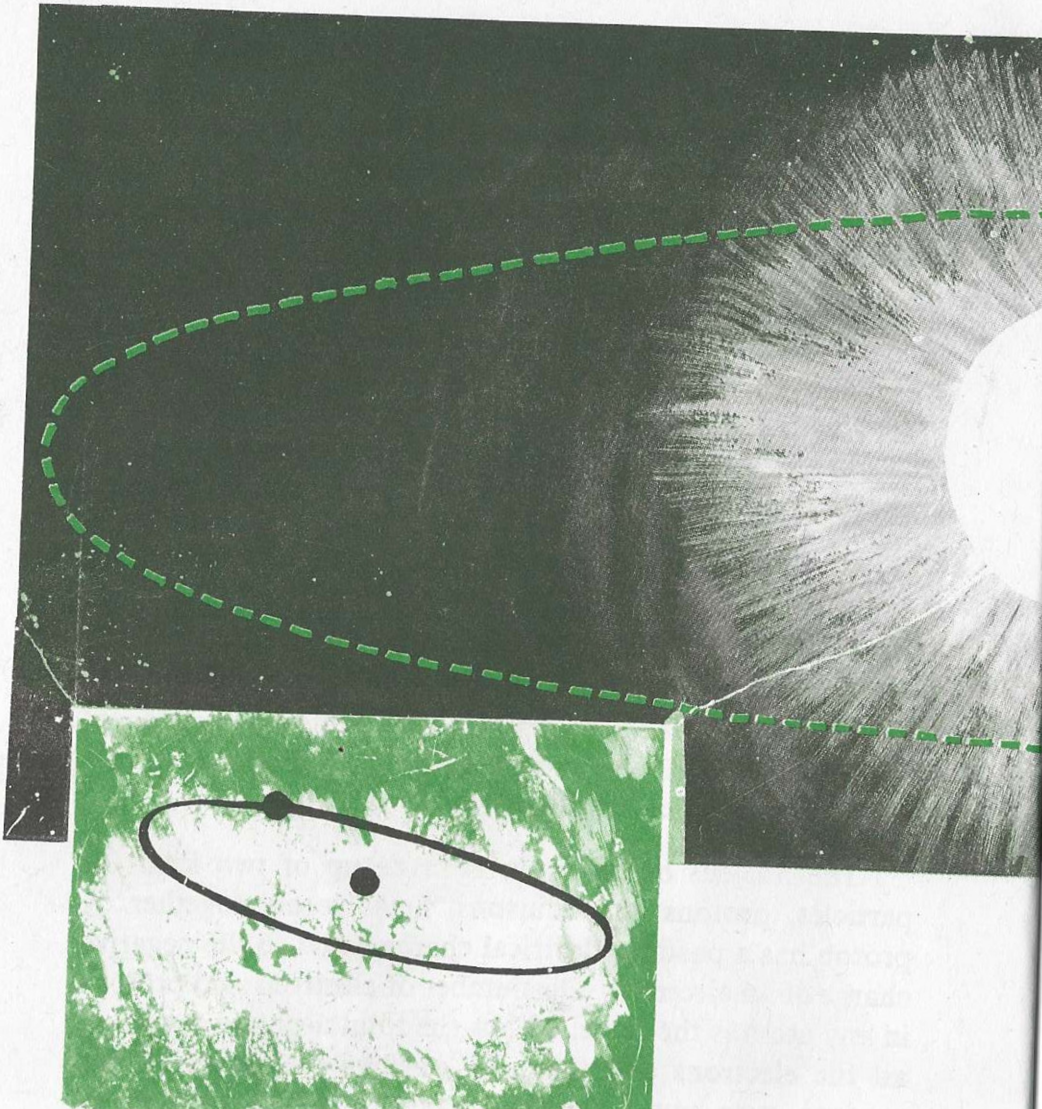
ting it up into fragments until we have a fragment which is still iron but cannot be split any more. This fragment is known as an atom meaning a thing which cannot be cut up into smaller bits.

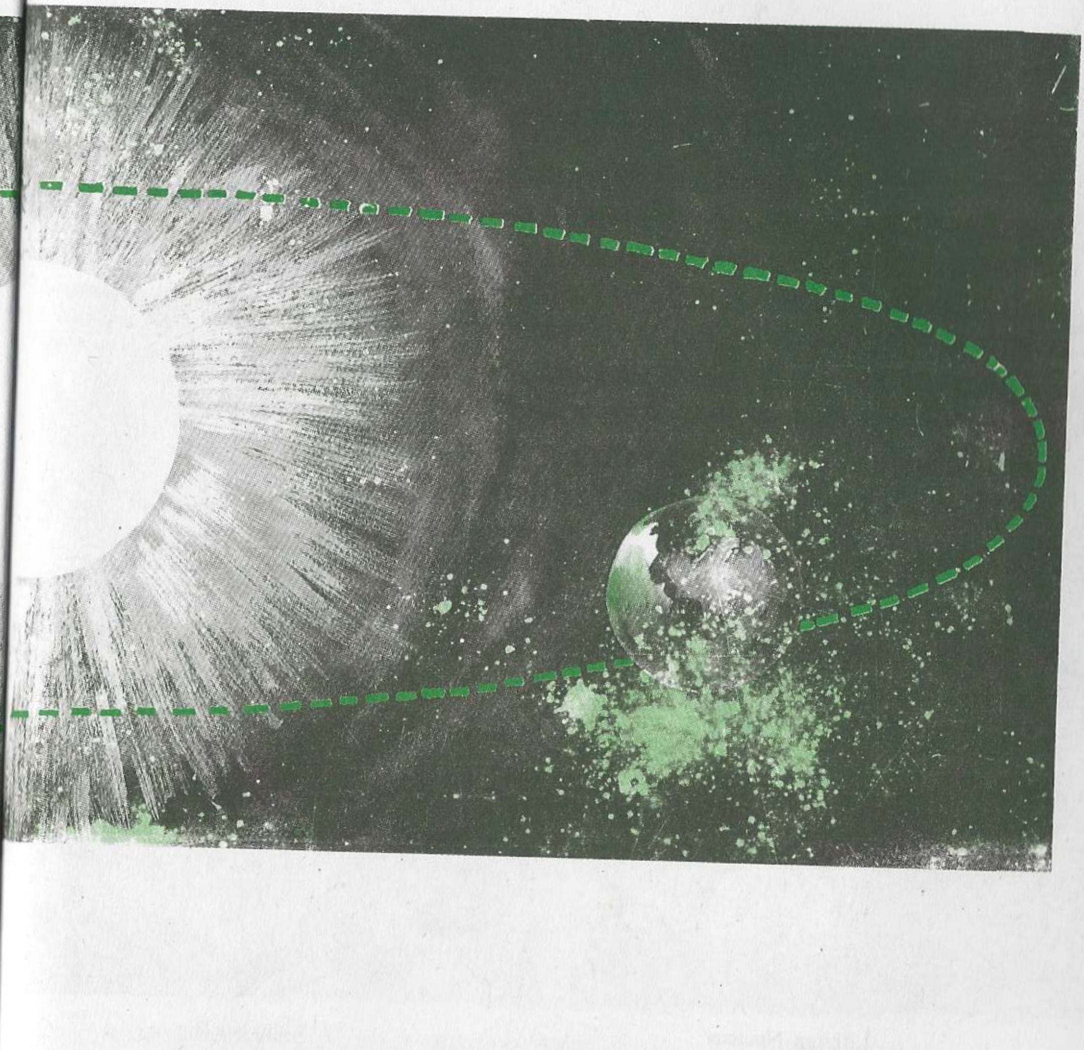
Many ancient Greek philosophers believed that all matter could be endlessly broken up into smaller and smaller particles by grinding. But others insisted that the particles could not be ground smaller than a certain size. They were the ones who conceived of the idea of the atom.

An atom is largely empty space. It is built up of numbers of mainly three types of particles the proton, the electron and the neutron. All atoms have a centre, known as a nucleus, in which the greater part of the weight of the atom is concentrated. Around an atom's nucleus, tiny, very light particles called electrons keep circling at dizzy speeds in particular orbits in much the same way as planets move in particular orbits round the sun. Electrons carry a small negative electrical charge.

The nucleus of the atom is made up of two kinds of particles, protons and neutrons, held closely together. A proton has a positive electrical charge equal to the negative charge of an electron. The number of electrons and protons in any atom is the same: Thus the total negative charge of all the electrons and the total positive charge of all the protons even out. The atom as a whole is electrically negative.

A neutron has no electrical charge. It has about the

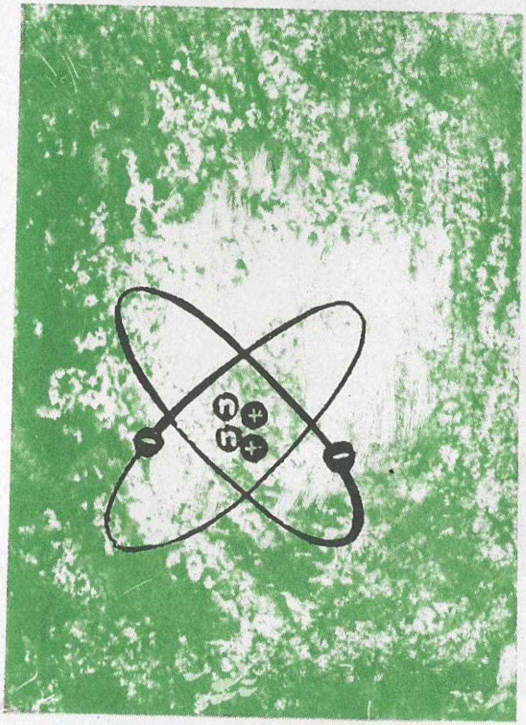




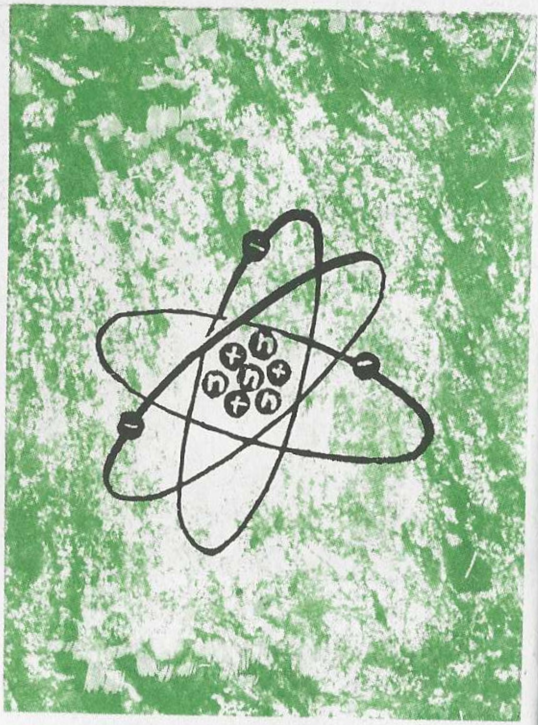
The action of electron spinning around the nucleus is much like the orbit of the earth around the Sun

same mass or weight as a proton.

The properties of an element depend upon the number of electrons or protons in its atom. The neutrons merely make up the mass. The atoms with one proton are hydrogen



Lithium Nucleus



Helium Nucleus

atoms. All with two protons are called helium and those with three protons are called lithium.

In some cases atoms of the same element have different numbers of neutrons and therefore different masses. These

different forms of the same element are called isotopes. They only differ in their masses and have the same chemical properties. For instance, the element hydrogen's atom is usually made up of only one proton and no neutron.

A Denterium Atom **B Tritium Atom** **C Hydrogen Atom**

But another variety of the hydrogen atom exists, though it is quite rare, and this has a proton and a neutron. It is called deuterium. A third kind which has to be made artificially has one proton and two neutrons and is

known as tritium.

When it was discovered that atoms were made up of particles, scientists tried to break them up further. They found that some of the electrons, specially those which were farthest from the nucleus, could be easily removed from the atom. In fact, when a glass rod is rubbed with silk, some of the electrons are rubbed off from the glass and get attached to the silk. This leaves the piece of silk negatively charged. The glass rod shows a positive charge as the loss of some of its electrons leaves it with an unbalanced, surplus positive charge.

But when it came to breaking up the nucleus of an atom, scientists found that they had a very hard nut to crack. The protons and neutrons were held so tightly together that it seemed as if nothing could pull them apart.

In the meantime, Marie and Pierre Curie had discovered a new element, radium. This discovery brought to light a new class of elements. All these elements had the common property of being 'radioactive'. An element is called radioactive when it gives off certain waves or particles and breaks down by itself. The new elements were not only radioactive but also among the heaviest of the known elements. Their great weight seems to make them top-heavy; they keep splitting of their own accord at a uniform rate. Uranium, the heaviest of the natural elements, belongs to this class.
When radium splits, it gives off two kinds of particles

and one kind of rays. The particles have been named alpha and beta. Beta particles are electrons, while alpha particles are nuclei of helium, i.e. they are made up of two protons and two neutrons. The rays are called gamma rays and are very powerful.

The particles given off by radium travel at high speeds. This gave scientists the idea that the particles could be used as bullets to attack the nucleus of an atom. The beta particles were too light to be useful. But the alpha particles were quite heavy. There was one difficulty however. The alpha particles were positively charged. We know that the nucleus of an atom has also a positive charge. Now, it is a law of electricity that like charges repel or push away each other. But since alpha particles given off by radium moved at a high speed, it was hoped that they might not be pushed away easily. Scientists had some success but the bullets knocked off only small parts of the nucleus.

Then Chadwick discovered neutrons. Earlier scientists had been unaware of their existence. The neutron proved very suitable as a bullet, as it had no electrical charge. So the nucleus did not push it away. Enrico Fermi, an Italian scientist, tried to hit the nuclei of elements with fast and slow moving neutrons. He had some success but when World War II started, he was forced to flee to America.

Some German scientists made the amazing discovery that the nucleus of uranium, when struck by neutrons, fell

apart into two nearly equal parts and gave off enormous quantities of energy.

Now uranium occurs in nature mainly in the form of two isotopes called U-238 and U-235. The two occur mixed together, and in the uranium as found in nature less than one per cent is U-235. It is this isotope which falls apart when struck by slow-moving neutrons. When this happens,

Albert Einstein

huge quantities of energy and a few neutrons are set free. It was expected that these free neutrons would, in their turn, strike against more U-235 nuclei and break them up. If this happened again and again, the result would be a chain reaction. This action results in the blast of an atom bomb.

U-238 behaves in a different way. It absorbs the neutrons that strike it. So it cannot lead to a chain reaction.

These findings were reported to the famous scientist, Einstein, who was then in America. He saw that this discovery could lead to the making of a deadly super-bomb —the atom bomb. He informed the President of the United States of America who ordered that the work be taken up.

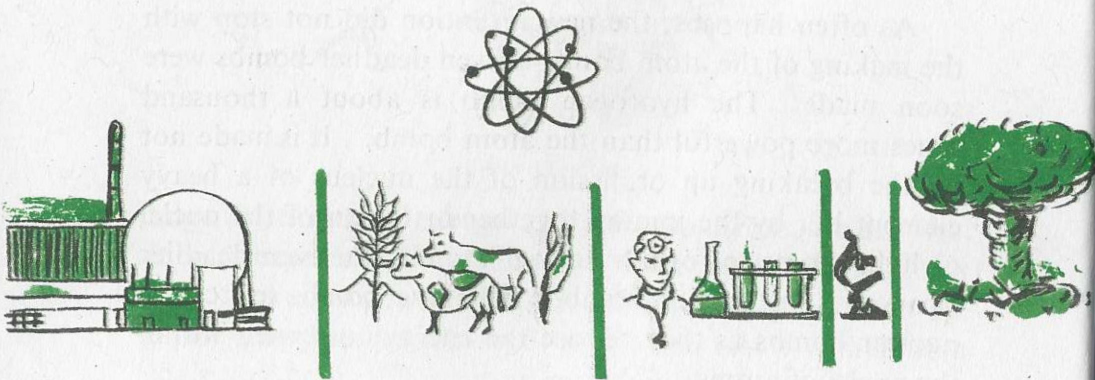
There were still two problems before the scientists who set out to make the atom bomb. The first was to make sure that a 'chain reaction' took place. The second was to separate enough of U-235 from natural uranium to make a bomb.

Work on the atom bomb was started in 1940. Enrico Fermi led the team that was to test the chain reaction. This test, completed on December 2, 1942, turned out to be a success.

As often happens, the new invention did not stop with the making of the atom bomb. Even deadlier bombs were soon made. The hydrogen bomb is about a thousand times more powerful than the atom bomb. It is made not by the breaking up or fission of the nucleus of a heavy element but by the joining together or fusion of the nuclei of light atoms to form a heavier atom. An even deadlier weapon is the cobalt bomb. All these bombs are called nuclear bombs as they release the energy contained within the nuclei of atoms.

The invention of nuclear bombs has changed the whole concept of war. Gone are the days when wars dragged on for years. A single nuclear bomb can wipe out a city. Long-range missiles with nuclear war heads stand poised to fly at distant targets at the pressing of a button. The havoc that may be caused during a war in which both sides use nuclear weapons freely is difficult to imagine. For the first time in history, people are haunted by the fear of an all-out nuclear war which will wipe out all life from the face of the earth.

The invention of the atom bomb placed greater power of destruction in the hands of man than he had ever had. At the same time it brought hope for the future. Our natural sources of power, coal and oil are being used up at a very rapid rate and the day may come when they are used up entirely. Power provides us with so many amenities necessary for our comfort and with the growth of civiliza-



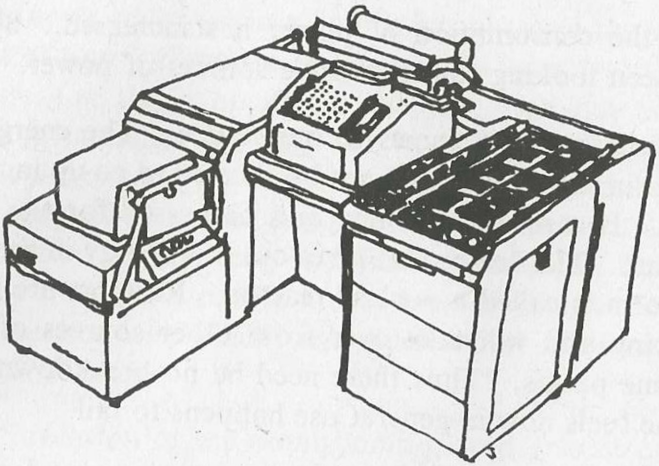
Peaceful uses of atomic energy

tion, the consumption of power has increased. So man has been looking for alternative sources of power.

Here the atom comes to our rescue. The energy contained in its nucleus need not be allowed to go up in a single blast. It can be controlled and harnessed for the benefit of man. The device that gives out this energy in a controlled form is called a nuclear reactor. Reactors are already working and will take over from other sources of power as time passes. Thus there need be no breakdown if any of the fuels now in general use happens to fail.

Nuclear reactors are already performing wonders. They are supplying power for ships and submarines and are producing electricity in nuclear power stations. The unique feature of nuclear energy is that a small package can carry an enormous amount of energy which can last a long time. In August 1958 the submarine 'Nautilus' travelled under the ice-cap at the North Pole crossing from the Pacific to the Atlantic Ocean with only a single charge of nuclear fuel. Nuclear power is also likely to prove suitable for prolonged flights in space. It will supply the power for future colonies on the moon if we decide to build them.

New uses are being found for nuclear power every day. The atom bomb may be said to have triggered the changes which have brought in the Nuclear Age. Many of its wonders are already with us, but many more are yet to come.



ELECTRONICS

Strictly speaking, the invention and use of electronics came long before anyone even thought of the atom bomb. But the progress in electronics has been so fast during recent years that it appears to be a much later event in science. Electronics is one of the most live sciences and industries of the present day.

To understand what electronics means, we must first know what happens inside a wire when an electric current flows through it. We know that the metal of the wire is made up of atoms packed close together. We also know that each atom has a nucleus around which a number of electrons are moving at great speeds.

When an electric current is sent through the wire, some of these electrons are pushed forward in a steady stream from one end of the wire to the other. This stream of electrons works heaters, lights and other electrical devices as it passes in an unbroken circuit through them.

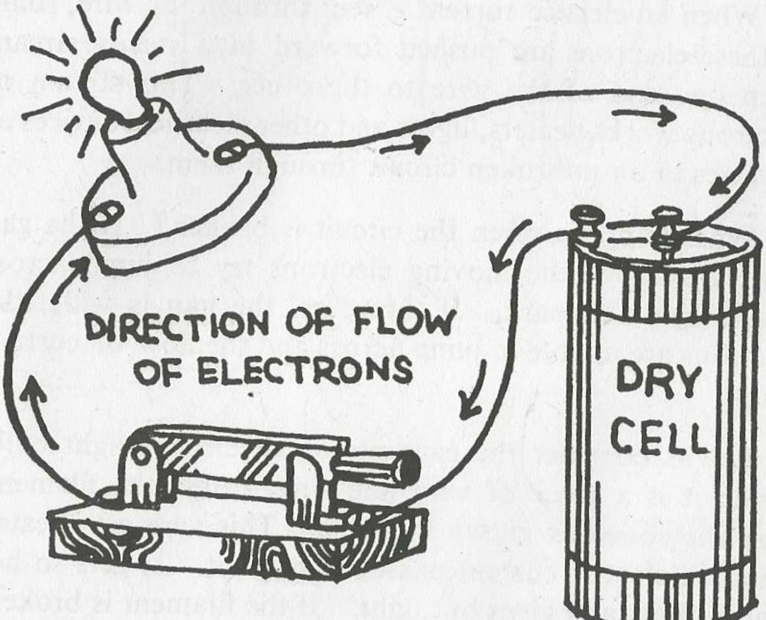
What happens when the circuit is broken? If the gap is very narrow, the moving electrons try to jump across it and cause a spark. If, however, the gap is wide, the electrons are unable to jump across and the flow of current stops.

Let us consider the example of an electric light bulb. Inside it is a piece of very fine wire, called the filament, which is coiled or zigzag in shape. This wire gets heated when an electric current passes through it. It gets so hot that it glows and gives out light. If the filament is broken, the current cannot pass through it and it stops glowing. We then say the bulb is fused and replace it.

Thomas Alva Edison (1847-1931) was the inventor of the electric light bulb. He made many unsuccessful attempts before he was able to perfect it. In 1883 he made

a special kind of bulb by placing a metal plate inside it, some distance away from the filament. When he gave the plate a positive charge, a current started flowing across, but it stopped when the plate was given a negative charge.

Edison neither knew nor cared what this meant: He



was busy improving the light bulb and did not want to be side-tracked. Anyway, he made a note of what he had seen and took out a patent, just in case it might prove useful later on. Then he placed the bulb in a drawer of his table and forgot all about it.

What he had discovered came to be called the 'Edison effect' after him. To understand what it is, it is necessary to know something about the behaviour of electrons. Normally electrons are strongly bound to the atom and at ordinary temperatures very few of them can escape from the atom. However, when a metal is heated to an adequately high temperature a considerable number of electrons escape just as bubbles do when you boil water. We might say that electrons are 'boiled off' on heating. The emission of electrons from heated wires is known as thermionic emission. In Edison's bulb when the plate had a positive charge, it attracted or pulled to itself the negative electrons 'boiled off' from the hot filament across the gap in-between. But when the plate was negatively charged, it repelled or did not allow the electrons to come near it. The flow of current therefore stopped.

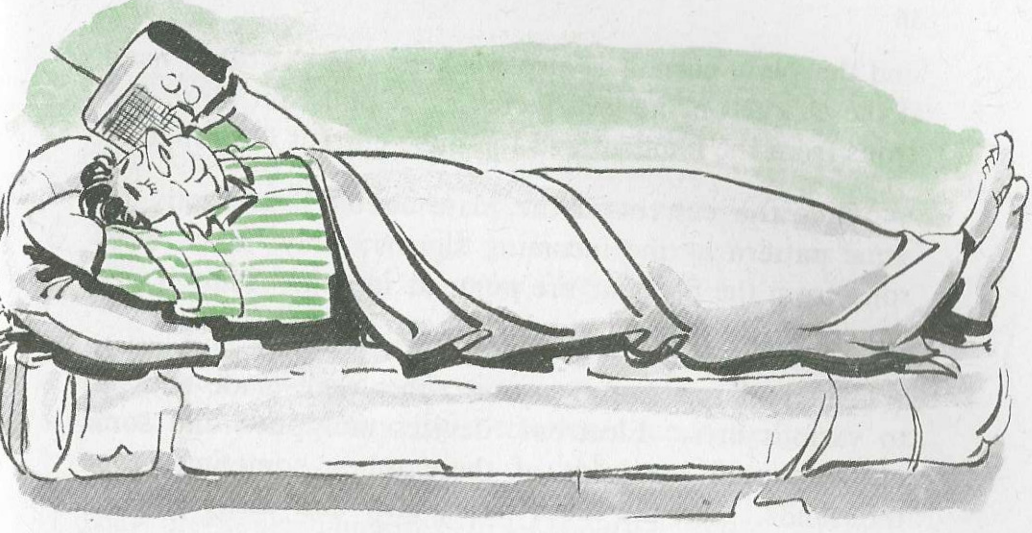
The Edison effect thus showed that a current flowed between the filament and the metal plate if the plate was positively charged.

Years later, John Ambrose Fleming, an English electrical engineer, improved this bulb into what is now called a thermionic tube or valve. A valve is any device which allows the flow of liquid or gas or current in only one direction and blocks the flow if it is reversed. This thermionic tube was used as a rectifier. A rectifier changes alternating current into direct current. An alternating current is one which reverses its direction several times a second. If it is connected to the plate, it will give it positive and

negative charges alternately. But with the thermionic valve the current flows through the plate circuit only when the plate is positive and stops when it is negative. So the result would be a current always flowing in one direction only.

In 1907, Lee De Forest, an American inventor, improved the thermionic tube further. He placed a 'grid' or a wire gauze between the filament and the plate without touching either. The tube could now be used as an amplifier. He named it the 'audion' and it is also called the 'triode'.

All the groundwork for the radio had now been done



In 1888, a German scientist, Heinrich Hertz, had proved that the forces of electricity and magnetism can leave one body and travel to another body in the form of an electromagnetic or wireless wave.

A radio transmitter turns sound into electromagnetic waves or signals. When these are sent over a long distance, they grow weak, and it is not possible to hear them unless they are amplified or made more powerful. The incoming signals are connected to the grid of the triode. When the grid has a positive charge, it pulls out a stream of electrons from the filament. This stream passes on to the plate through the holes in the grid, and the current flows through the plate circuit. If the charge on the grid becomes weak, it pulls out fewer electrons from the filament,

and the plate current is also weaker. On the other hand, if the charge on the grid increases, it pulls out more electrons from the filament and the plate current is stronger.

Thus the current in the plate circuit has exactly the same pattern as the incoming signals; only more electrons from the filament are pumped into it. Thus it gets amplified to the point at which it can be heard.

Different types of electronic tubes were made and put to various uses. Electronic devices multiplied and some of them used hundreds of these tubes, sometimes even thousands. But the tubes were bulky and easily broken. Scientists began to search for something much smaller and stronger.

At the end of World War II, a team of scientists started this search at the Bell Telephone Laboratories in America. They were Walter Brattain, William Shockley, S. O. Morgan, G. L. Pearson and John Bardeen. In 1947, they invented the 'transistor' using certain substances known as semi-conductors.

Usually substances are classed as conductors or non-conductors. Conductors allow an electric current to pass through them. Examples of conductors are silver and copper. Non-conductors such as glass or bakelite, on the other hand, do not allow the passage of an electric current through them. Semi-conductors such as silicon and germanium, however, are in a class by themselves. In normal conditions, they are non-conductors, but after proper

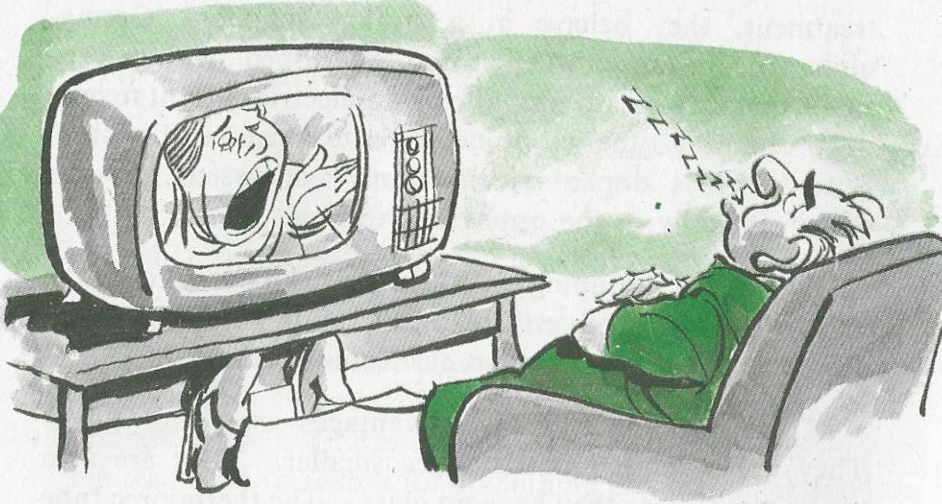
treatment, they behave in a strange manner. Germanium, for instance, when mixed or 'doped' with a very small quantity of arsenic, allows an electric current to pass only one way—the usual negative to positive direction. But when it is 'doped' with gallium, it allows the passage of current only in the opposite direction.

By careful grouping of these two kinds of crystals, scientists have produced rectifiers, amplifiers and other devices similar to the various electronic tubes used.

Transistors have many advantages over the tubes. They are several hundred times smaller. They are also much stronger as they have no glass. The thermionic tube moreover takes time to get hot before it starts working and the heat is a great nuisance. The transistor starts working as soon as the current is turned on and does not produce any heat. Finally, it is much easier and cheaper to produce.

The use of electronics has indeed changed the world. Starting with simple devices like the radio we have now got devices which have to be seen to be believed. An electronic device about as big as a cigarette case has been used to adjust the heartbeat of a patient whose heart had a timing defect. It is called the heart pace-maker. Some heart patients have electronic devices implanted in their chest to keep the heart going.

Clothes are being made with tiny electronic devices woven into them so that the wearer can keep himself warm or cool by the mere flick of a switch. Houses are being

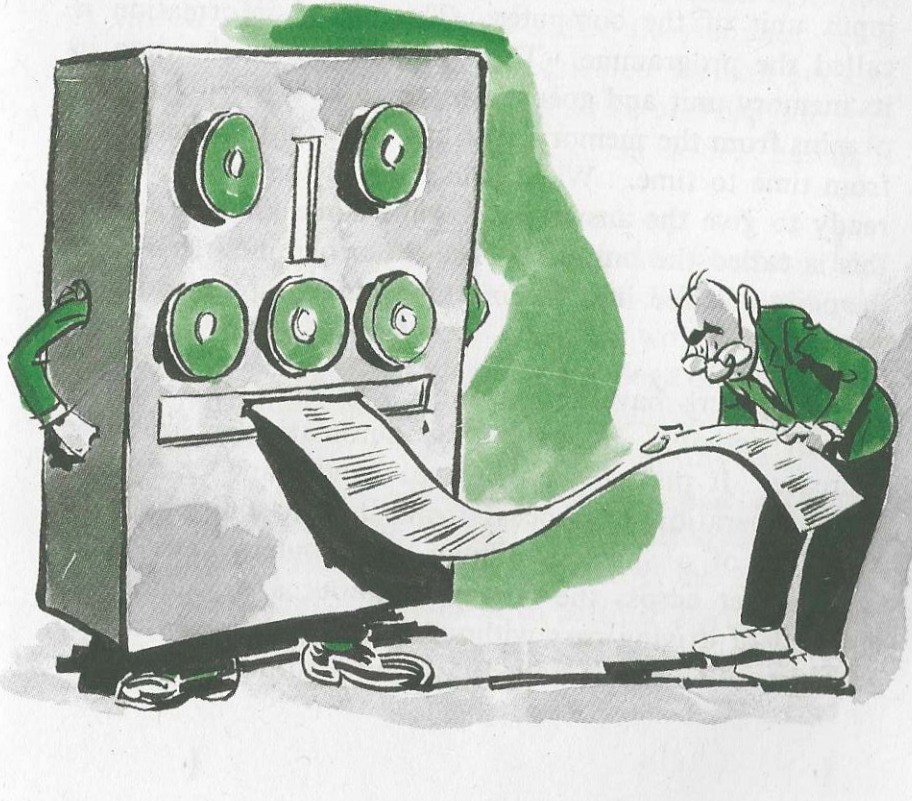


built, walls of which contain electronic units to adjust the room temperature as it rises or falls. Radar gives early warning of approaching enemy aircraft in all types of weather, and works equally well during day or night. Fishing trawlers and submarines fitted with electronic devices are the last word in spying. From a distance of several kilometres from the coast they can pick up radio messages, watch missile tests, track land and air traffic and map important sites. Electronics has also produced 'laser'—an intense beam of light—which can burn holes in a metal sheet several metres away. A laser beam flashed on the moon spread out to a diameter of three kilometres after having travelled a distance of 400,000 kilometres.

Modern electronic computers have been given different

names—super-calculators, brains in boxes, man-made brains, thinking machines, etc. This suggests that they have some capacity which enables them to function more or less like the human brain.

The modern computer is an electronic wonder. It is a machine which can calculate thousands of times faster than a man. What is more, it is never



tired and makes no mistakes. It can process reams of figures, weigh and judge every item and come up with a decision in a few seconds. It can control an operation according to this decision; and if anything goes wrong, it profits by the experience and corrects its original decision accordingly. It is almost human in the way it works. There is a fear that one day it will replace man and in many walks of life, it may even become his master.

The way in which the computer works reminds us of the working of the human mind. All the data and instructions needed to solve a problem are fed into the input unit of the computer. This coded information is called the programme. The computer stores the data in its memory unit and goes ahead to solve the problem. It obtains from the memory unit any data that are required, from time to time. When it has solved the problem, it is ready to give the answer or to take some kind of action; this is called the output. Once the programming is done properly and fed into the machine, the computer does all the rest.

Computers have found their way into almost every human activity. In industries, automation is on the increase. It makes it possible to handle and control an entire operation or process from start to finish without the help of a single workman. Computers have flown an air-liner across the Atlantic without a navigator. A method of driving cars without drivers is being tested by scientists. This, it is hoped, will put a stop to accidents!

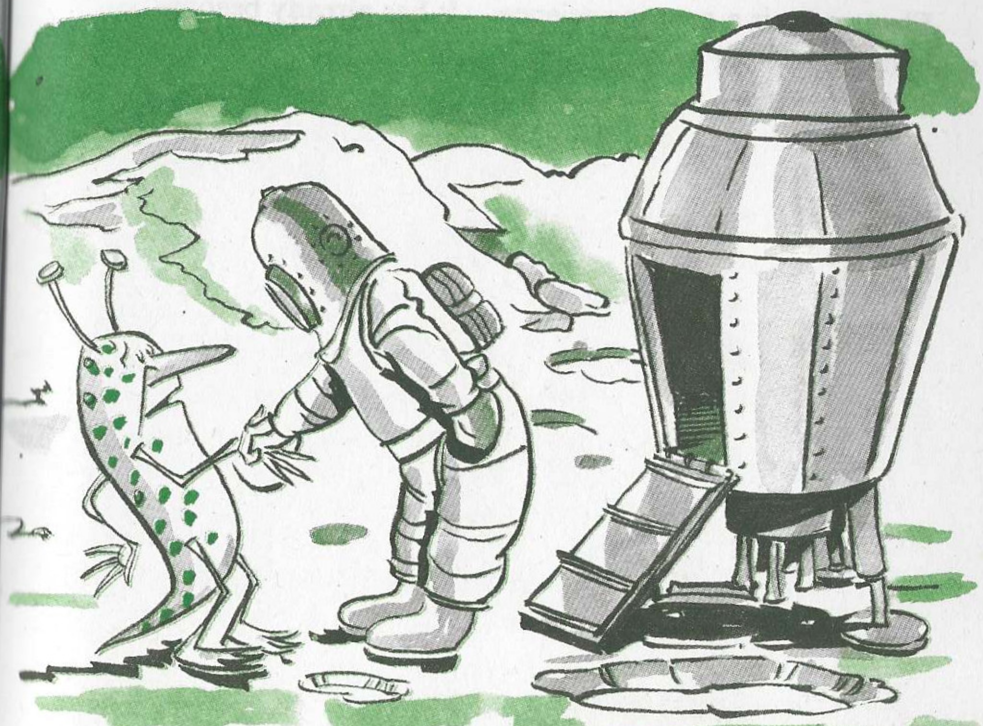
Future wars will use computers and other electronic devices for almost every purpose. Computers will be used to plan the strategy of war. The strength of the fighting units, their locations, supplies, transport, arms and ammunition will be fed into a computer and it will come up with a plan of action. The use of transistors has made computers so compact and sturdy that they can be moved about in trucks or helicopters.

It is possible to guide a missile accurately to targets hundreds, even thousands of kilometres away. What is more wonderful is that it is possible to track an enemy missile in its flight and destroy it before it reaches its target. A missile travels many times faster than sound; yet a computer can not only mark and calculate its path but also send up another missile in time to strike and explode it in mid-flight. The use of radar and spying devices has been mentioned already.

The flight of American astronauts to the moon and back in the spaceships Apollo XI and XII in 1969, the greatest human adventure of all time, would have been impossible without electronics. Every stage of the journey was planned and worked out beforehand by computers. Electronic instruments kept contact with the spaceship throughout its flight. Computers checked and corrected the speed and direction of the flight and directed the landing on the moon. They were ready to stop the flight and bring the astronauts safely back to earth if anything went wrong. The whole show from start to finish was worked

by electronics.

There seems to be no end to what computers can do.



They are being taught to translate books from one language into another and to play games of chess!

Electronics is a growing science. It has already become a giant and is still growing.

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